Institute of Paper Science and Technology
Atlanta, Georgia

IPST Technical Paper Series Number 784

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April 1999

Submitted to
Water Research

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Improving the Efficiency of Impulse Drying Sludge

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Abstract

Impulse drying works well at low polymer dosage, probably because thinner sheets are dewatered more efficiently, albeit at the cost of reduced throughput. The process is relatively insensitive to the ingoing solids level in the 20-30% range, but the efficiency decreases at solids levels of 40% or more. Differential scanning calorimetry shows that both bound and free water are removed in the process, with the free water being preferentially lost. Multiple impulses progressively improve the dewatering efficiency.

In impulse drying a hot roll contacts a sheet of sludge and the steam pressure generated at the roll-sheet interface expels some of the water in liquid form. We have previously described laboratory and pilot applications of the technology (Banerjee *et al.*, 1998a; Banerjee *et al.*, 1998b; Mahmood *et al.*, 1998) with both primary sludge and mixtures of primary and secondary material. Several full-scale trials have also been successfully run (Banerjee and Beckley, 1999). We now explore the effect of polymer dosage, sheet thickness, initial solids, and the effect of multiple impulses on the efficiency of the process, and study the distribution of residual bound and free water at various stages of impulse dewatering.

Experimental

In order to determine the effect of initial solids on impulse performance, belt-pressed primary sludge was obtained from Riverwood International's Macon, GA, mill at either 20 or 30% solids. A portion of the 30% sludge was sent to Ashbrook Corporation, Houston, TX, where it was further pressed to 39% solids in a belt press simulator. For the polymer work, belt-pressed mixed sludge (70% primary and 30% secondary) was collected from Georgia-Pacific's Big Island, VA, paper mill. The sludge was conditioned with Praestol K133L (an acrylamide copolymer manufactured by Stockhausen Inc.) at 4-10 mg/g of dry solids in increments of 2 mg/g. Sludge was collected for impulse drying as it emerged from the belt press. Characteristics of the belt-pressed sludge at different polymer dosages are presented in Table 1.

Laboratory impulse drying was conducted with an MTS electrohydraulic press described earlier (Banerjee *et al.*, 1998a). This instrument delivers a controlled pressure pulse to a small cake of sludge at variable dwell through a heated platen. Differential scanning calorimetry (DSC) curves were recorded on a Perkin-Elmer DSC7 with TAC 7/DX controller using Perkin-

Table 1: Characterization of sludge from Big Island.			
(mg polymer/g dry solids)	percent solids	average sheet thickness (mm.)[2]	percent ash at 550°C
4	23.82	5.1	16.06
6	23.96	5.7	14.01
8[1]	24.84	6.9	14.24
10	24.67	6.4	12.14
[1]value used routinely by the mill; [2]average of 15 determinations			

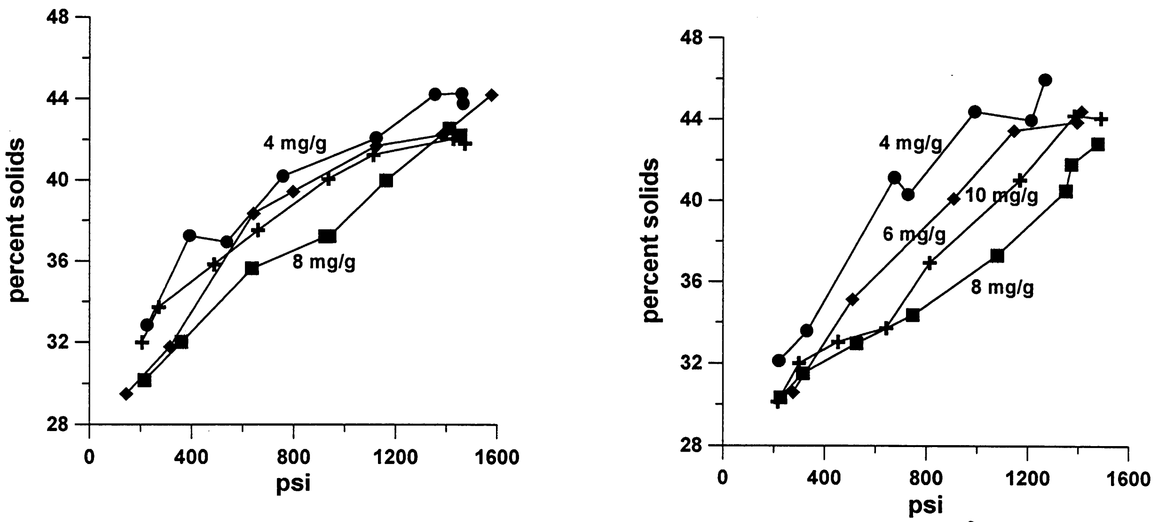

Figure 1: Effect of polymer dose on impulse drying at 200 (left) and 300°C (right). Symbols: • 4; ◆ 6; ■ 8; ✚ 10 mg/g dry solids

Elmer Pyris 3.01 software. A two-point calibration was conducted using the melting point and peak area of indium and distilled, degassed water. In a typical experiment 15.0–20.0 mg of sludge were placed in an aluminum cup, and an aluminum lid was crimped into place. The sample was placed in the DSC7 and cooled from 10°C to –30°C at a rate of 10°C/min. The freezing water resulted in an exothermic peak at approximately –8.0°C. The evolved heat was calculated by integration of the peak area.

Results and Discussion

Effect of polymer dosage

Figure 1 shows the effect of polymer dosage on impulse drying at 200 and 300°C, respectively. For both temperatures, dewatering was best at the lowest concentration of polymer used, 4 mg/g of dry solids; the outgoing solids were lowest at 8 mg/g. A thinner sheet is expected to dewater better under impulse conditions, albeit at a possible cost of throughput. Hence, we conclude that changes in polymer dosage induce real performance differences.

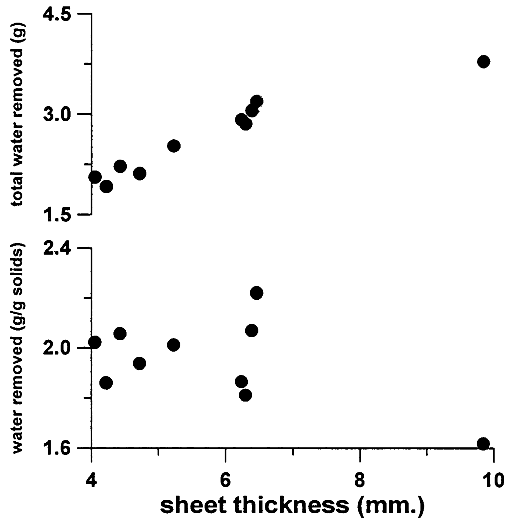

Figure 2: Effect of sheet thickness on water removal.

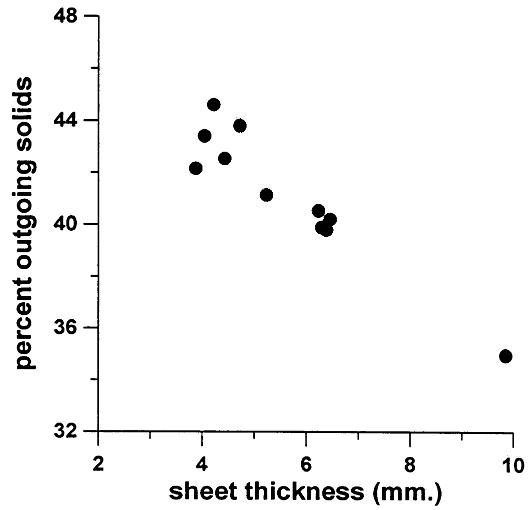

Figure 3: Effect of sheet thickness on impulse drying.

Also, increased polymer dosage decreased the ash content of the belt-pressed sludge (Table 1), which could be due to an increase of biological flocs and cell debris in the sludge cake. This would reduce dewatering efficiency owing to the increased secondary content of the sludge. In any event, the best results are clearly obtained with low polymer use, which should reduce dewatering costs.

Effect of sheet thickness

The water removed per gram of dry solids and the total water removed during impulse drying was calculated through a mass balance, and the results are presented in Figure 2 as a function of sheet thickness. A small decrease in water removal per gram of dry solids with increased sheet thickness is evident from Figure 2. On the other hand, the total water removed increased significantly as the sheet thickness increased. The effect of sheet thickness was isolated from that of polymer effect by impulse drying sludge sheets of various thicknesses at 300°C, 1200 psi peak pressure, and a constant polymer dosage of 8 mg/g. The results are presented in Figure 3, which shows that a 6 mm increase in sheet thickness (from 4 to 10 mm) decreases outgoing solids from 44 to 35%. As noted in Table 1, a 50% reduction of polymer dose from 8 to 4 mg/g reduces sheet thickness by 1.8 mm. This reduction translates to a 3% increase in outgoing solids from the Figure 3 relationship. Impulse drying experiments conducted under optimal conditions showed up to an 8% increase in percent solids as the polymer dosage was reduced from 8 to 4 mg/g (Figure 1, 300°C). We attribute the solids gain in excess of 3% to changes in sheet structure due to reduced polymer dosage. The dense compact sheets formed at high polymer dosage are, perhaps, more difficult to impulse dry as compared to the more porous sheets produced at low polymer doses.

Table 2: Effect of initial solids on dewatering efficiency[1]	
percent ingoing solids	increase in percent solids
20	17
30	23
39	6
[1]run at 1000 psi and 350°C, at a 700 ms dwell	

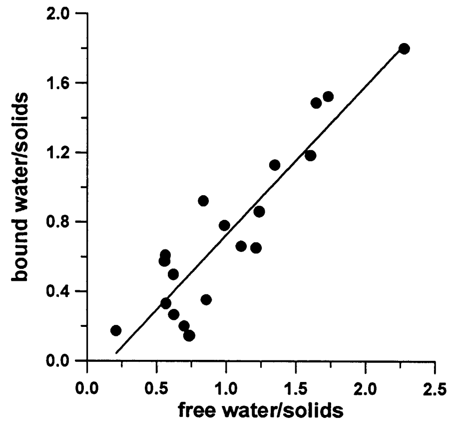

Figure 4: Relationship between free water and bound water in impulse dried sludge

Effect of initial solids

Measurements were made at 350°C at a dwell time of 700 ms. Dewatering increases linearly with applied pressure, and the results reported here are for 1,000 psi. The application of pressure alone (without heat) removed about 2 percentage points of water; however, we have shown in pilot work that belt blinding occurs under these conditions. Little or no blinding results when heat and pressure are simultaneously applied.

The effect of ingoing solids on dewatering efficiency is illustrated in Table 2. Although the results are presented for a single pressure, the trends are maintained across the 400-2,000 psi range. Note that the efficiency peaks at about 30% solids. At lower solids, the sludge matrix is probably too fluid for pressure dewatering to effectively occur. At the 39% level, the surface water may be depleted to the point where sufficient steam is not generated at the interface. In any case, the intermediate situation appears to offer the best combination of structure and surface moisture, and appreciable dewatering occurs. The practical aspect of this finding is that the sludge does <u>not</u> have to be extensively dewatered prior to the impulse; i.e., a relatively inexpensive belt press coupled to an impulse unit may offer the best option.

Differential scanning calorimetry (DSC) of sludge

The amount of free and bound water present in sludge can be calculated using the DSC crystallization curve that results from cooling a sample (Lee and Dun, 1995). Freezable water, defined as free water and any bound water that freezes, appears as a shoulder in the crystallization curve, i.e., as a depressed crystallization point. The remaining water is non-freezable bound water present in the sample. Figure 4 illustrates the relationship between free and bound water (normalized for solids content) for various impulse-dried sludge samples considered in this study. The bound water:free water relationship is linear, with a slope of slightly less than one, demonstrating that free water is preferentially lost. Impulse drying removes both bound and free water in roughly equal proportions. It differs in this aspect from most other means of mechanical dewatering, where only the free water is preferentially removed.

Effect of multiple impulses

Riverwood International's primary sludge was subjected to up to three impulses separated by 30 seconds. The results, shown in Table 3, demonstrate that the solids level rises with increasing number of pulses. As expected, the peak nip pressure increases as the sludge progressively consolidates (Banerjee, 1999). If the outgoing solids are averaged, we obtain 44.8%, 57.5%, and 63.8% for one, two, and three impulses, respectively. Although these values are not strictly comparable because of the differences in pressure, they do illustrate that increasing the number of pulses leads to decreasing returns. However, these gains could be offset by the increased capital and power costs. These conclusions are consistent with the DSC results, which demonstrate the loss of both bound and free water. If free water was the only species affected, then multiple impulses should have had little additional benefit once the free water had been substantially removed.

Table 3: Dewatering of Riverwood sludge under multiple impulse conditions[1]

no. of impulses	peak nip pressure (psi)			percent solids out
	1st impulse	2nd impulse	3rd impulse	
1	390			42.58
1	430			43.5
1	470			42.92
1	570			44.49
1	700			44.14
1	800			45.76
1	1000			46.07
1	1000			45.66
1	1600			48.12
2	470	606		50.9
2	630	1034		55.6
2	697	1148		54.8
2	741	1399		59.01
2	791	1520		59.24
2	990	1695		59.35
2	1339	1810		60.04
2	1688	1760		61.3
3	371	469	600	57.35
3	415	518	812	56.5
3	664	932	1111	62.02
3	686	938	1294	61.42
3	896	1505	1640	67.4
3	974	1430	1520	68.27
3	1410	1591	1669	68.28
3	1665	1607	1662	69.06

[1]impulse drying at 300°C at a dwell time of 1 second; the impulses were separated by 30 seconds.

Acknowledgment

We thank the TIP[3] program of the State of Georgia for financial support.

References

1. Banerjee, S., Phelan, P.M. and Foulke, R.W. (1998a), Method for dewatering solid-liquid matrices, US patent 5,718,059.
2. Banerjee, S., Mahmood, T., Phelan, P.M. and Foulke, R.W. (1998b), Impulse drying sludge, *Water Res.,* 32, 258-260.
3. Mahmood, T., Zawadzki, M. and Banerjee, S., (1998) Pilot study of impulse drying industrial sludge, Environ. *Sci. Technol.*, 32, 1813-1816.
4. Banerjee, S. and Beckley, J. (1999), Operational issues with impulse drying sludge, Proceedings of the 6th IAWQ Symposium on Forest Industry Wastewaters, Tampere, Finland.
5. Lee, D.J; and Hsu, Y.H., (1995), Measurement of bound water in sludges: a comparative study. Water Environmental Federation, 67, 310-316.
6. Banerjee, S. (1999) Method and apparatus for impulse drying, US patent pending.